

Investigation of Fleet Emissions using Enhanced Inspection and Maintenance Methods

**Daisy Thomas, Ph.D.
Gurdas S. Sandhu, Ph.D.**

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Outline

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Periodic Technical Inspection (PTI) Background

- European Union methods of inspection and maintenance, Periodic Technical Inspection (PTI) of exhaust emissions are out of date (No PN, no NO_x)
- This is progressing – PN is included in some member state PTI regulations and on 20 March 2023 EU published a recommendation¹ outlining guidelines around PTI PN measurement to aid harmonization
- Many groups are working to strengthen the EU PTI legislation (including incorporating a NO_x test)

¹ https://transport.ec.europa.eu/system/files/2023-03/C_2023_1796.pdf





Enhanced PTI Test Pilot – Opus Sweden





Aims and Objectives of the PTI Pilot Test Campaign

- PTI format:

Minimize
Test Time

Engine
Conditioning

Repeatability

NO_x
Protocols

- Vehicle pollutant trends compared to:

Vehicle
properties

Model type
approval results

Vehicle Euro
Standard

Vehicle PTI
Results

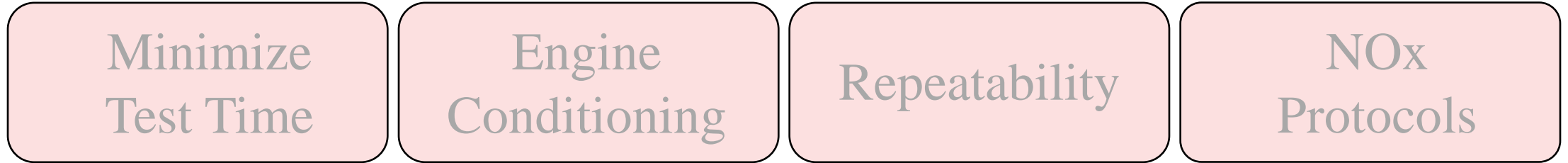
- Identification of high emitters
- Investigation of thresholds for pass/fail at PTI

3datx.com/ptipilot/
full presentation and
time-series charts for
each vehicle

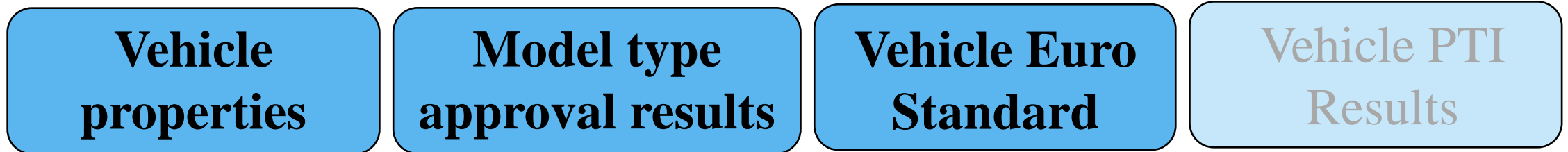


Aims and Objectives of the PTI Pilot Test Campaign

- PTI format:



- Vehicle pollutant trends compared to:



(Slide 14)

(Slide 18)

(Slide 20)

- Identification of high emitters
- Investigation of thresholds for pass/fail at PTI





Test Site - Borås, Sweden

- Tests were conducted at the Borås Opus Bilprovning PTI Test Centre



parSYNC iPEMS

Test Vehicle



parSYNC warmup and zeroing while vehicle is being prepared



OBD Logger



Tailpipe Sampling Probe



Device used - The parSYNC iPEMS

➤ Lightweight & Easy To Use

- Total System Weight: 6.7 kg (22.1 lb)
 - parSYNC[®] Weight: 4.1 kg (13.7 lb)
 - CUBE[™] Weight (with one battery): 2.6 kg (8.4 lb)

➤ Battery Life

- 4-5 hours typically

➤ GasMOD[™] Sensor Cartridge

- Electrochemical: NO (0-5000ppm) & NO₂ (0-300ppm)
- NDIR: CO₂ (0-20%), CO (0-15%)

➤ Particulates Sensor Cartridge

- PN/PM (10 to 10,000nm = 0.01 to 10µm)



The new parSYNC **FLEX** iPEMS

Gases – CO, CO₂, NO, NO₂ + **HC and O₂**

Particulates - Ionization, Scattering, and Opacity, **with advanced temperature control**

Diffusion charging-based particle number counter coming soon, to meet PTI requirements

Enhanced chiller and volatile particle removal

Hot-swap Milwaukee Li-Ion batteries for full-day of testing

Onboard display and data storage + WiFi Access-point

Full CAN + support for external sensors

Integrated GPS and Ambient Pressure, Temperature, Humidity

Integrated wireless OBD reader for LD and HD

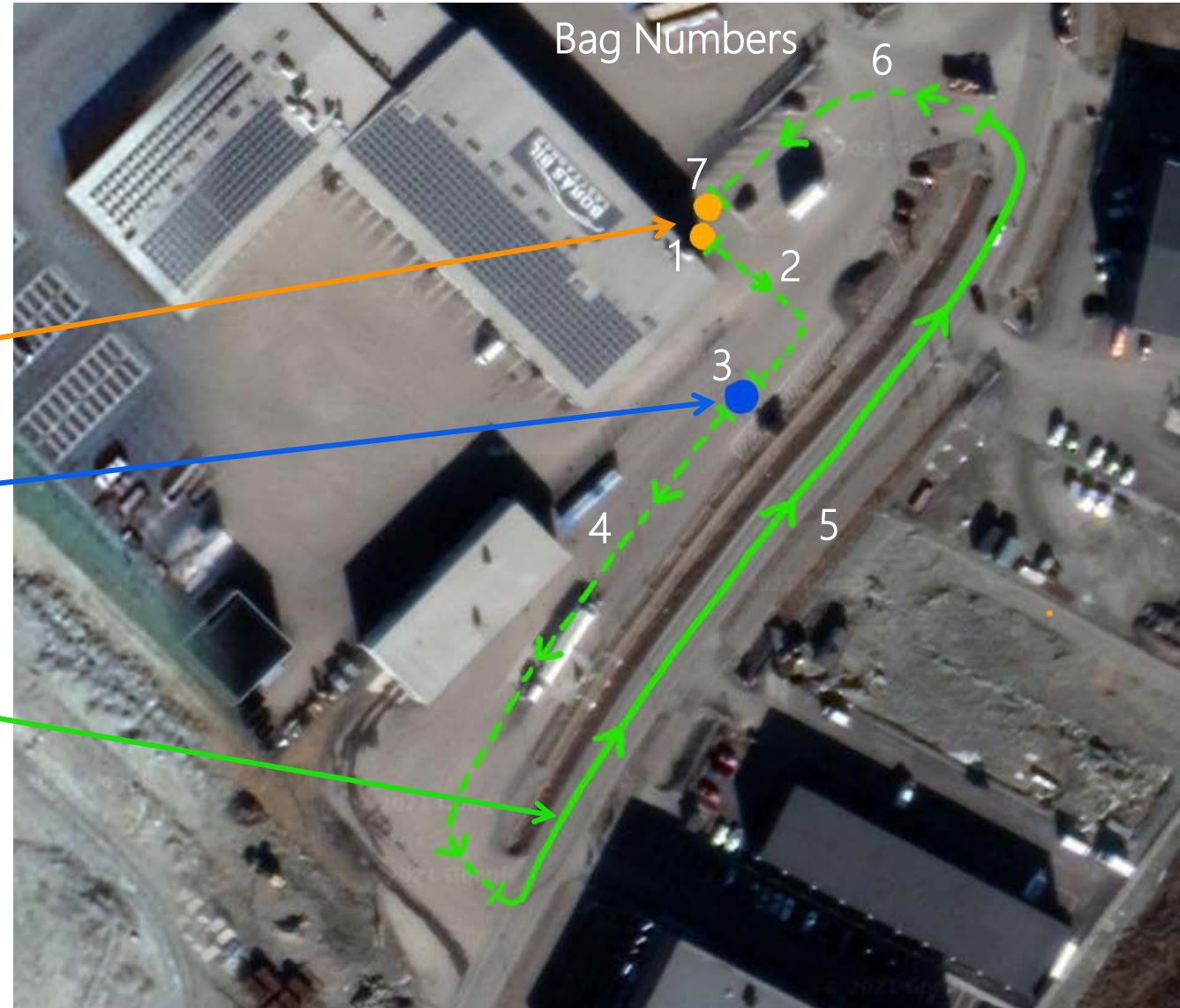
... and still light-weight (11 kg) and installs in minutes





Test Protocol – Extra 5 Minutes onto PTI

Bag No.	parSYNC Location	Description
0	Bench	Sample clean air while parSYNC is on the bench.
Zeroing	Bench	Zero the parSYNC. Idle the vehicle.
0	Vehicle	Move parSYNC to vehicle. Sample exhaust gas for ~10 seconds.
1	Vehicle	Idle protocol – 60 seconds of idle – conducted while car is at garage
2	Vehicle	Drive to emissions shed
3	Vehicle	High Idle – Follow standard PTI protocol for gasoline and diesel vehicles
4	Vehicle	Drive to NOx Acceleration test start point
5	Vehicle	Acceleration – <i>Idle for 10 seconds</i> , then accelerate quickly to 30 kph, then brake normally (not hard) to a complete stop, <i>idle for 10 seconds</i>
6	Vehicle	Drive back to garage.
7	Vehicle	Idle protocol – 60 seconds of idle
8	Bench	Disconnect parSYNC. Sample clean air for at least 60 seconds.
Zeroing	Bench	Zero the parSYNC.





Characteristics of the Test Fleet

Age, Mileage, Engine Size, Fuel, Euro Std

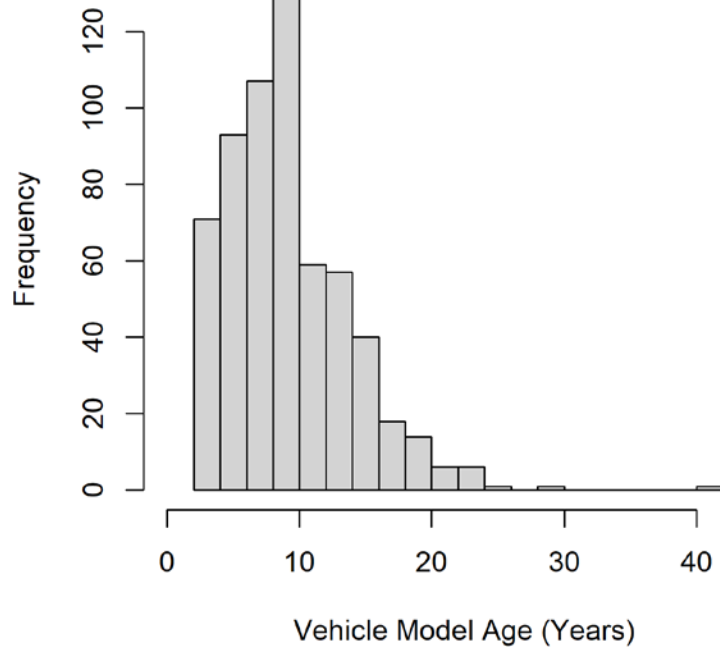




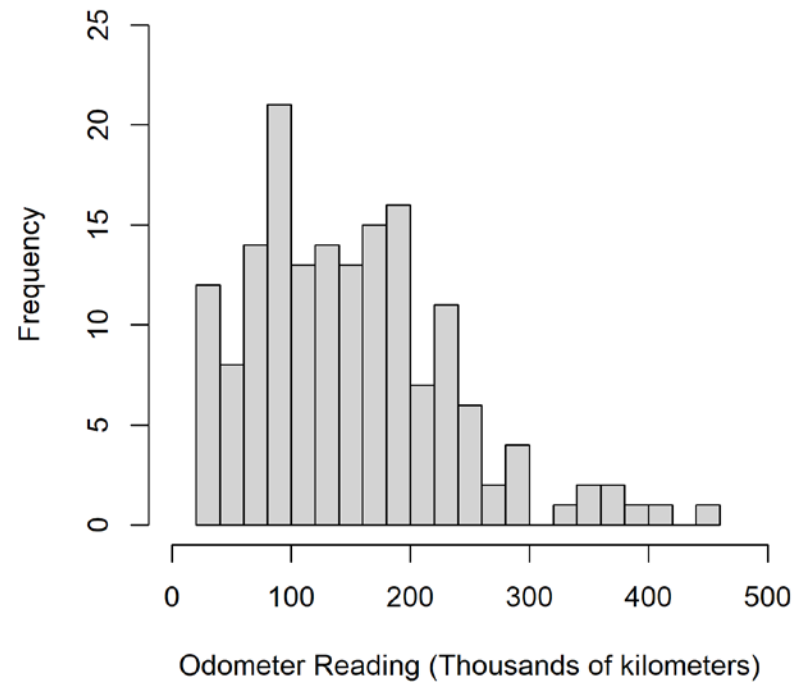
Fleet Composition – Vehicle and Engine Information

606 passenger vehicles underwent enhanced PTI testing at the Borås Opus Bilprovning PTI Test Centre during January 2021 – June 2022

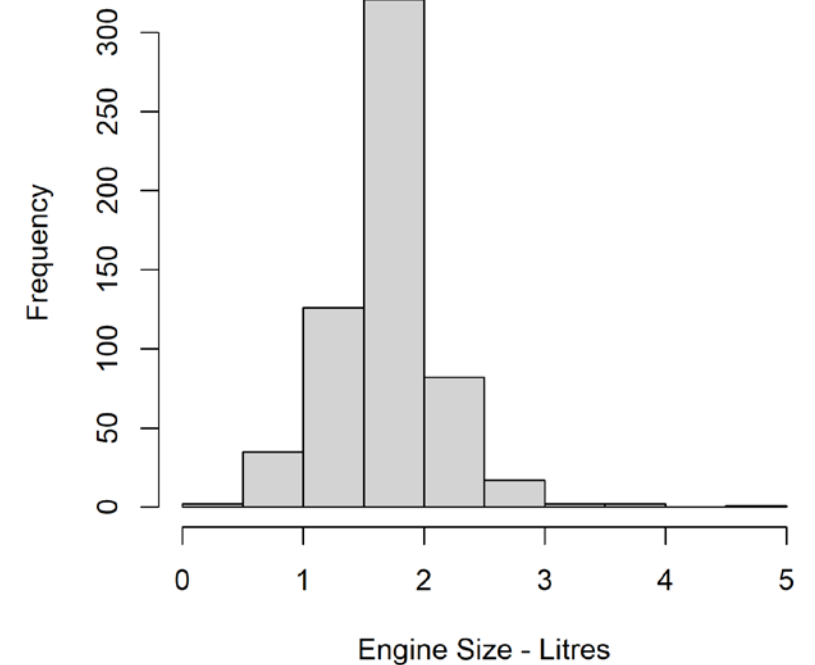
Histogram of Vehicle Model Age



Histogram of Vehicle Odometer Reading



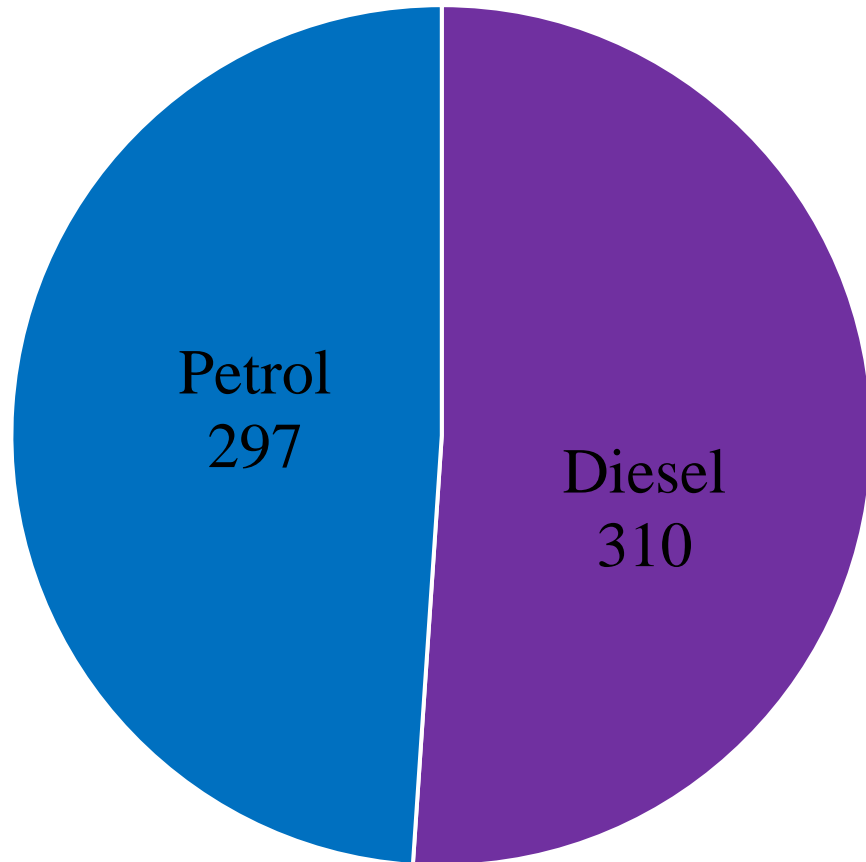
Histogram of Vehicle Engine Sizes



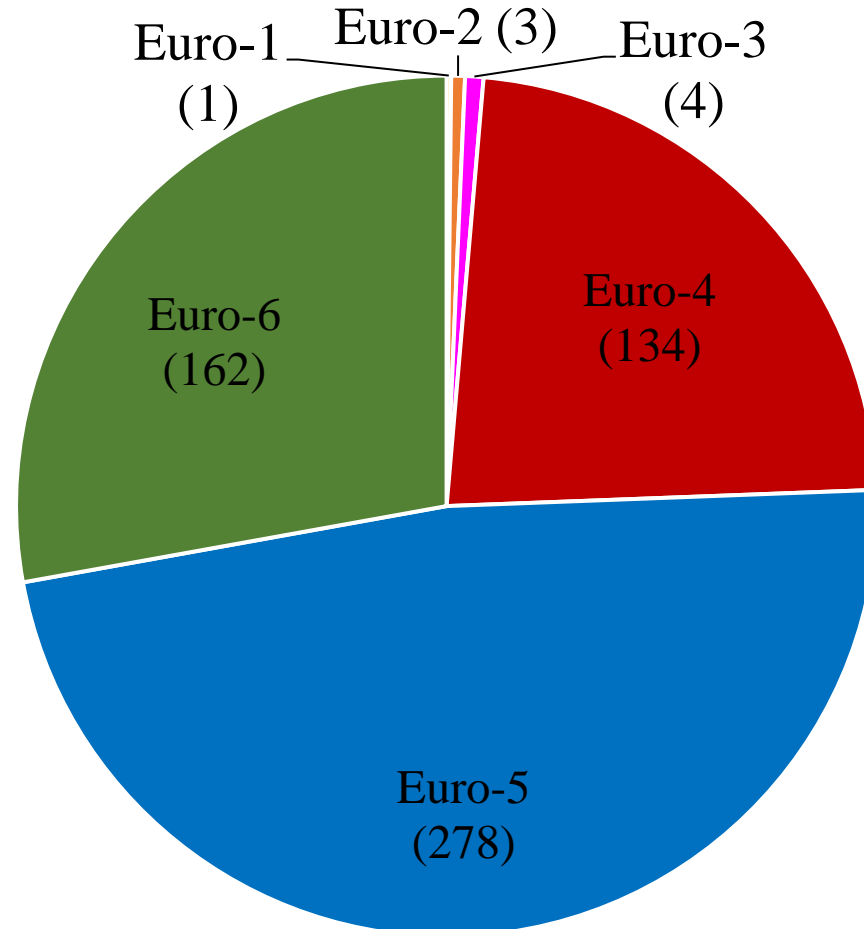


Fleet Composition – Fuel Types and Emission Standards

Fuel Type of Vehicles



Emissions Standards of Vehicles



EURO	MY*
1	1993
2	1997
3	2001
4	2006
5	2011
6	2015

* First registration

25 vehicles were of pre-Euro or unknown Euro standard



Vehicle Results Compared to Vehicle Characteristics

for PN, NO_x, and CO



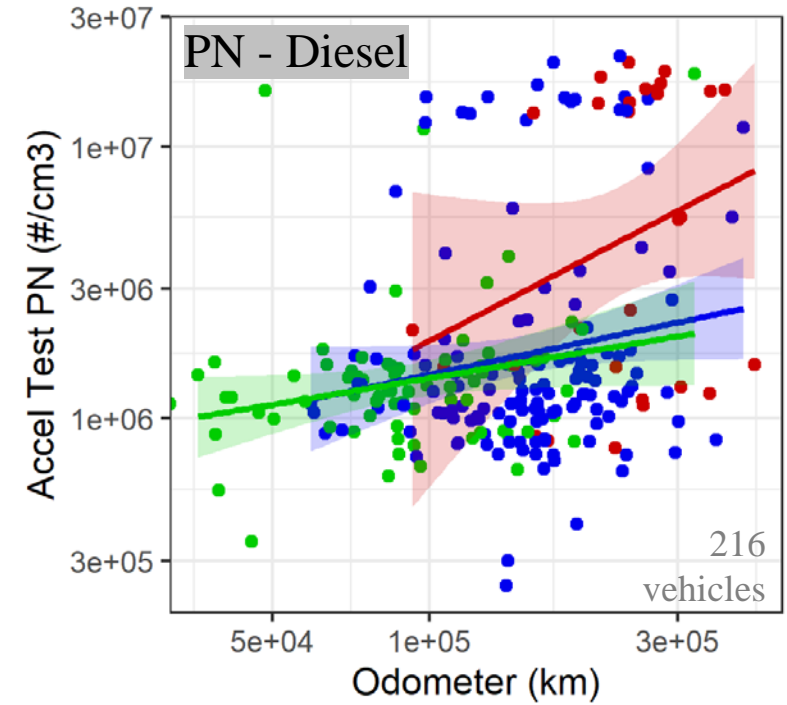
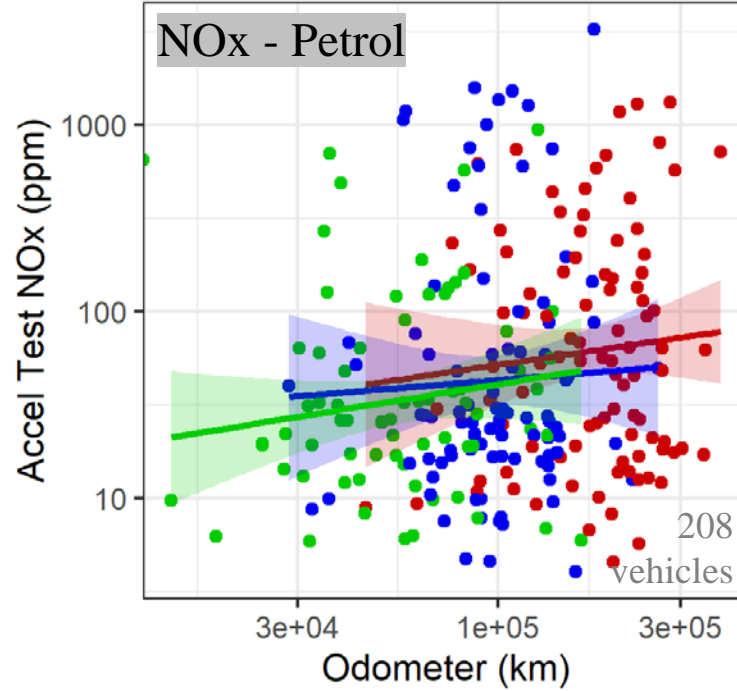
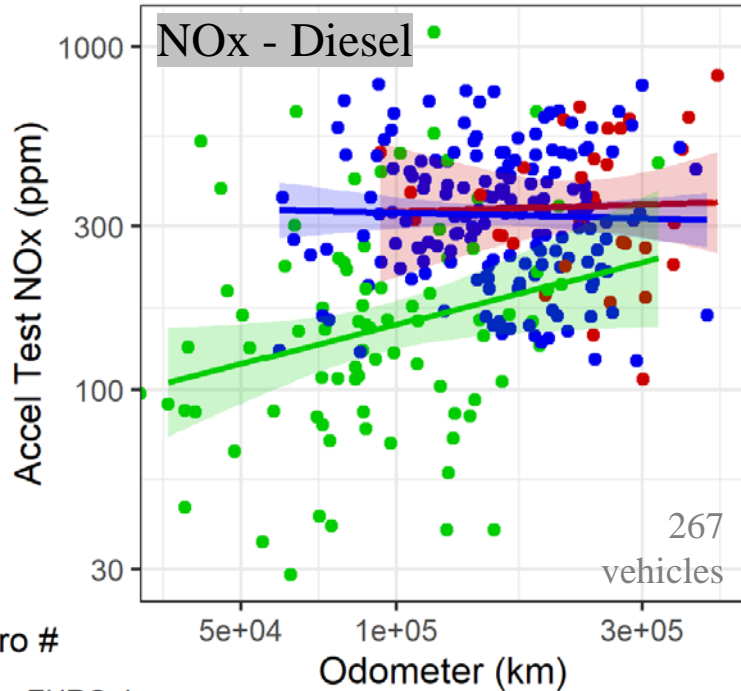


Effect of Mileage on Emissions Control

SCR equipped Euro-6 have significant deterioration (vs. non-SCR)

Modern 3-way catalysts have same deterioration as past decades

DPFs have deterioration but still reduce impact on PN



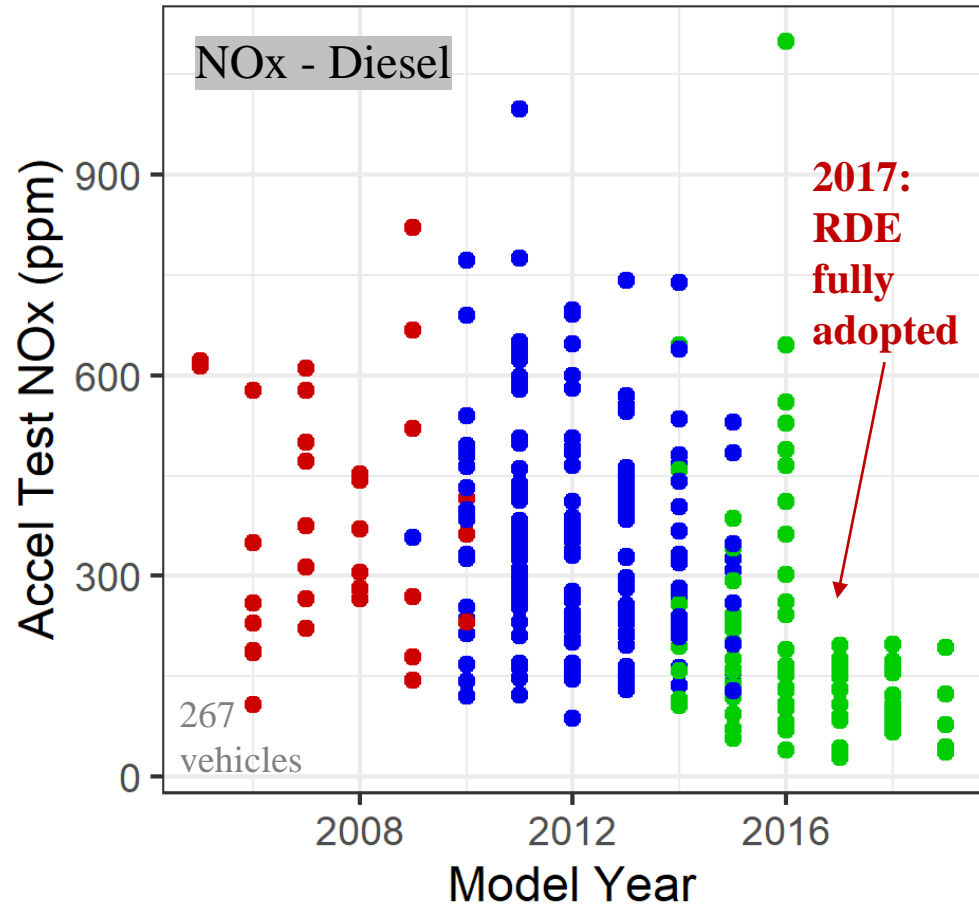
Euro #

- EURO-4
- EURO-5
- EURO-6



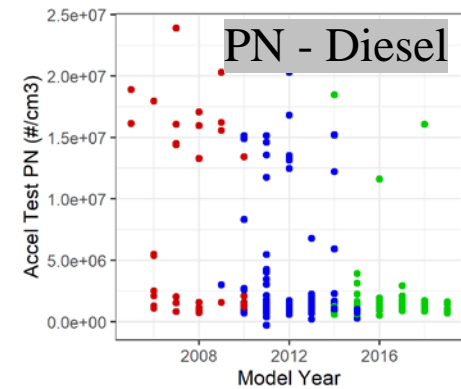
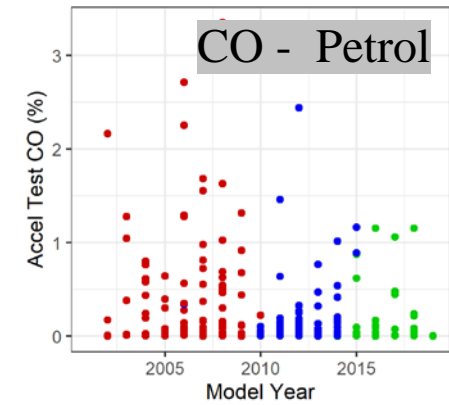
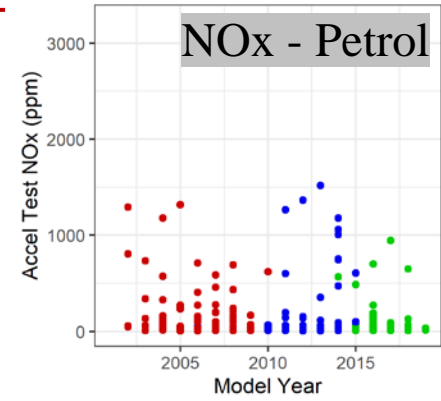


Model Year Trends



- Euro #
- EURO-4
 - EURO-5
 - EURO-6

No step decrease at model year 2017

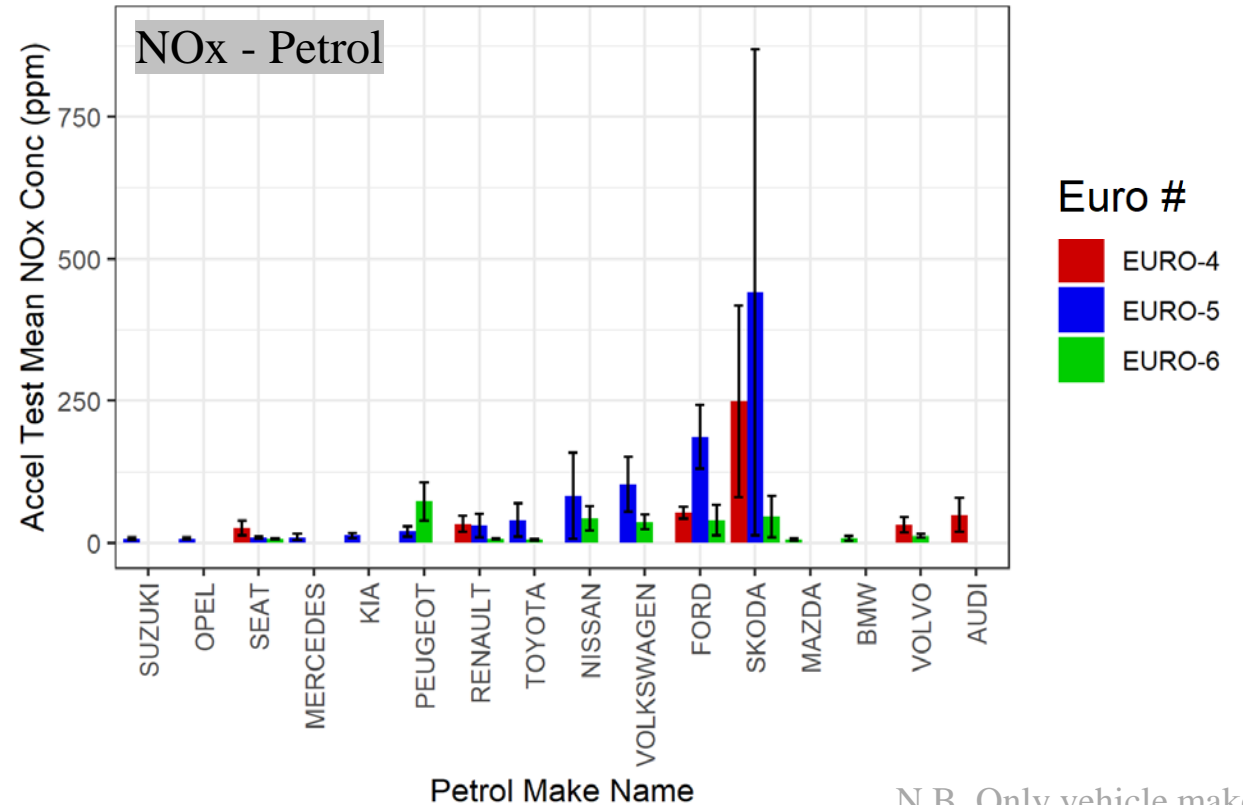
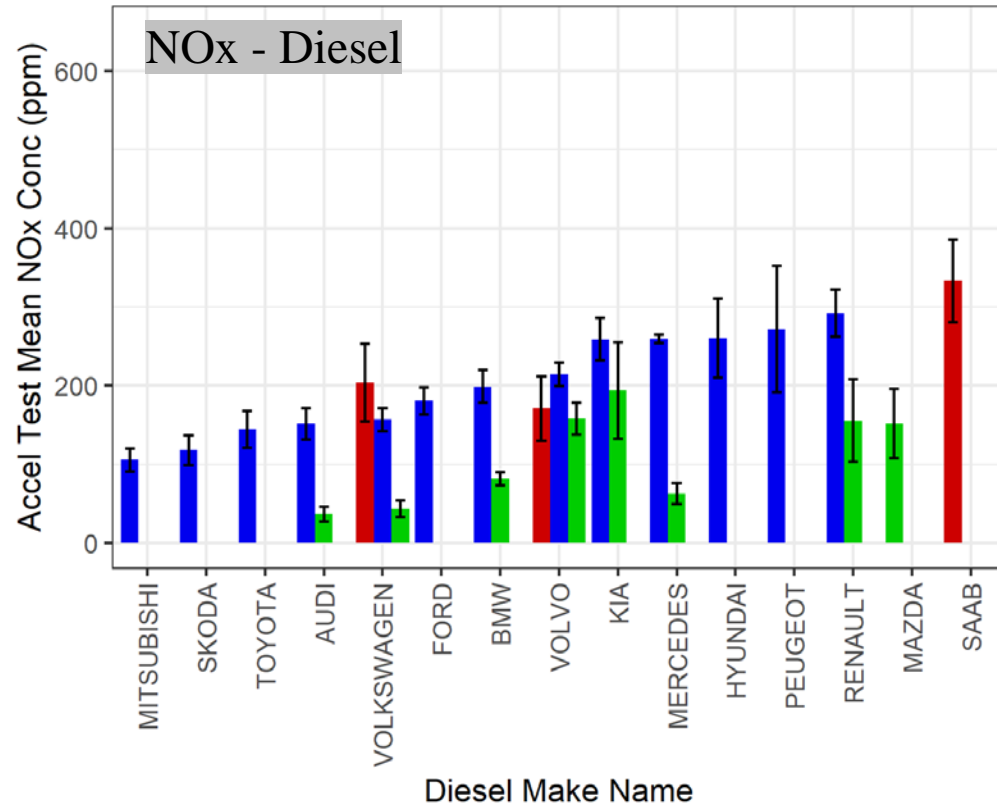




Manufacturer Trends

All Euro 6 diesels improve on Euro 5 (same for *almost* all petrols)

More variation seen between different vehicle makes from Euro 6 diesels than Euro 5 diesels and Euro 5 petrols than Euro 6 petrols



N.B. Only vehicle makes with at least 3 vehicles presented



Vehicle Results Compared to Model Type Approval Values for NO_x

RDE results for only 4 vehicles (3 petrol, 1 diesel) attained thus far...

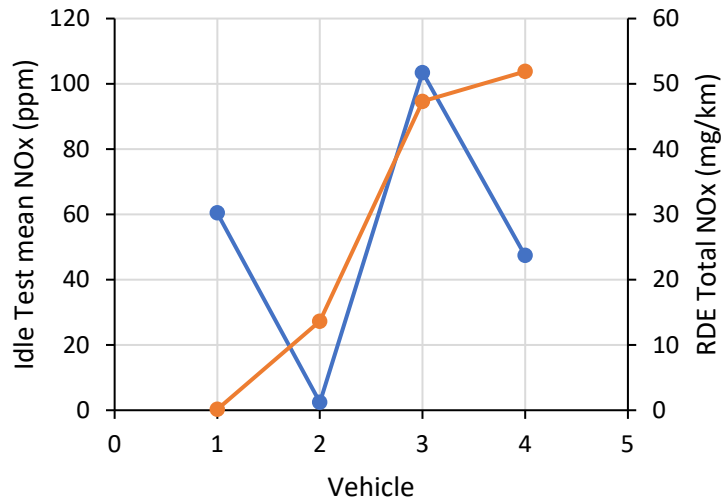




NOx Vehicle Results Compared to RDE Result

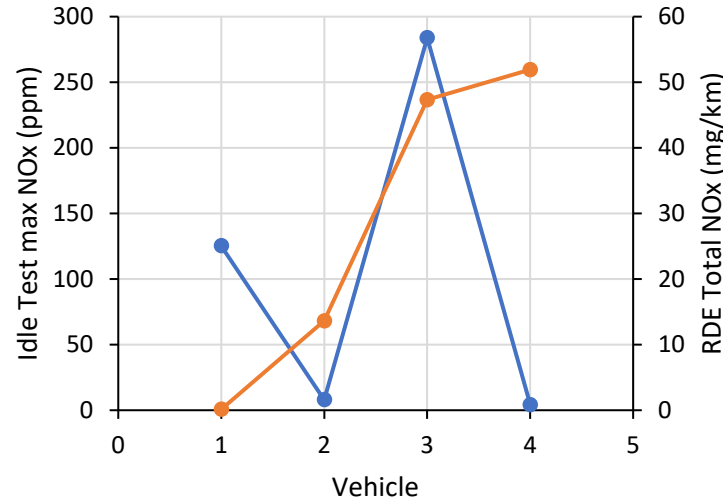
Acceleration test is most aligned with model type approval RDE. Thus, it is also superior as a PTI pass/fail criteria aimed at controlling real-world emissions – due to fewer false positive/negatives.

Idle NOx



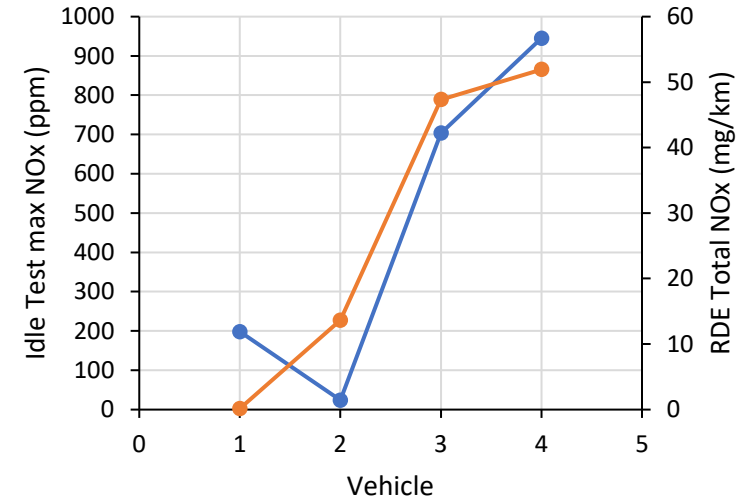
● average_mean_value_NOx (ppm)_Idle
 ● RDE_NOx_Total_(mg/km)

High Idle NOx



● average_max_value_NOx (ppm)_HighIdle
 ● RDE_NOx_Total_(mg/km)

Acceleration NOx



● average_max_value_NOx (ppm)_Accel
 ● RDE_NOx_Total_(mg/km)

* Trends do not change when mean values are used instead of max





Fleet-Average Trends by Euro Standards

for PN, NO_x, CO₂, and CO



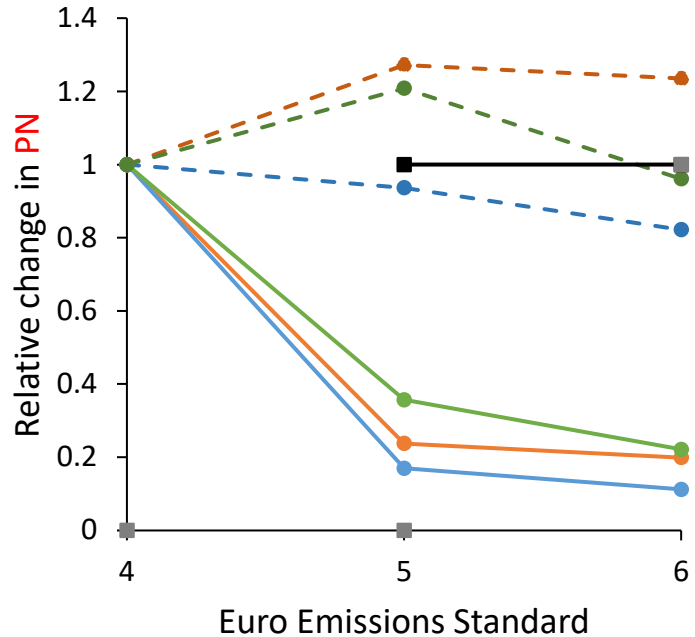


Evolution of fleet emissions by EURO stds – **Relative**

Euro 4 as baseline

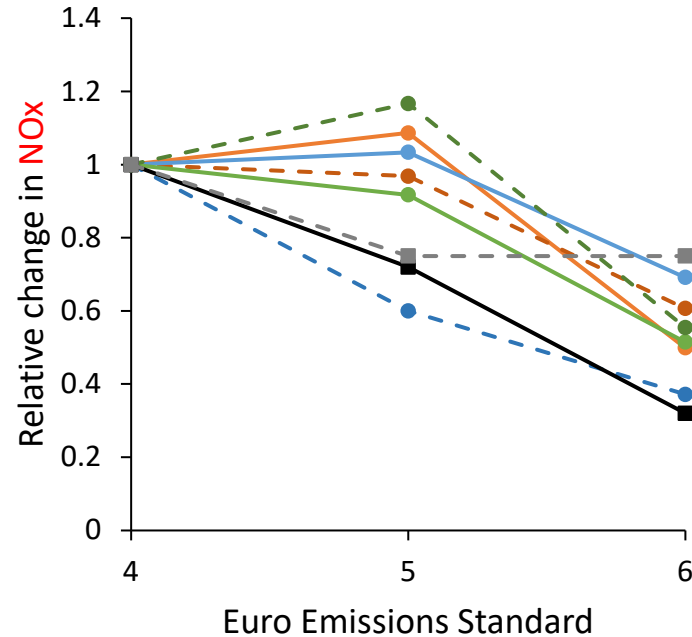
PN

- Petrol: High PN; need tighter stds
- Diesel: Standards working well



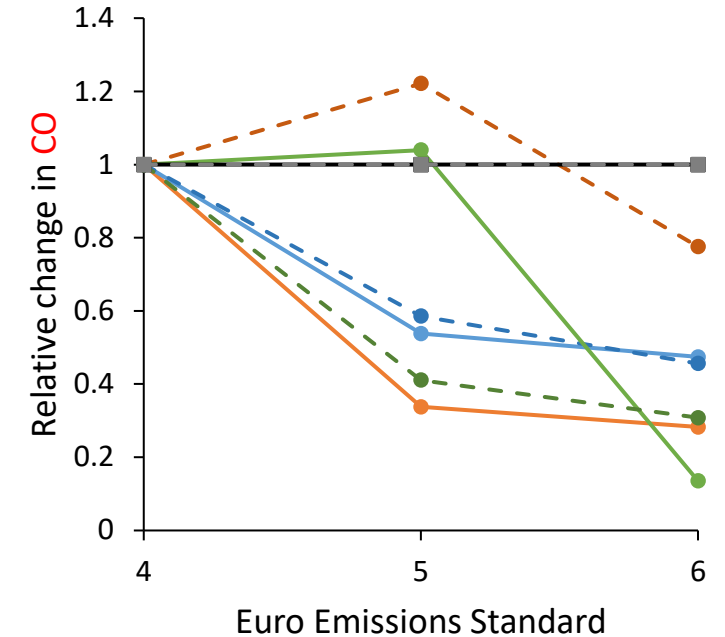
NOx

- Euro-6 reverses Euro-5 increase
- Diesel: RW reductions lagging stds



CO

- Overall progress okay
- Petrol: Idle CO lagging



—●— Diesel_Idle (#/cm3)
 - - -●- - - Petrol_Idle (#/cm3)
 —●— Diesel_HighIdle (#/cm3)
 - - -●- - - Petrol_HighIdle (#/cm3)
—●— Diesel_Accel (#/cm3)
 - - -●- - - Petrol_Accel (#/cm3)
—■— Diesel_Standard
- - -■- - - Petrol_Standard

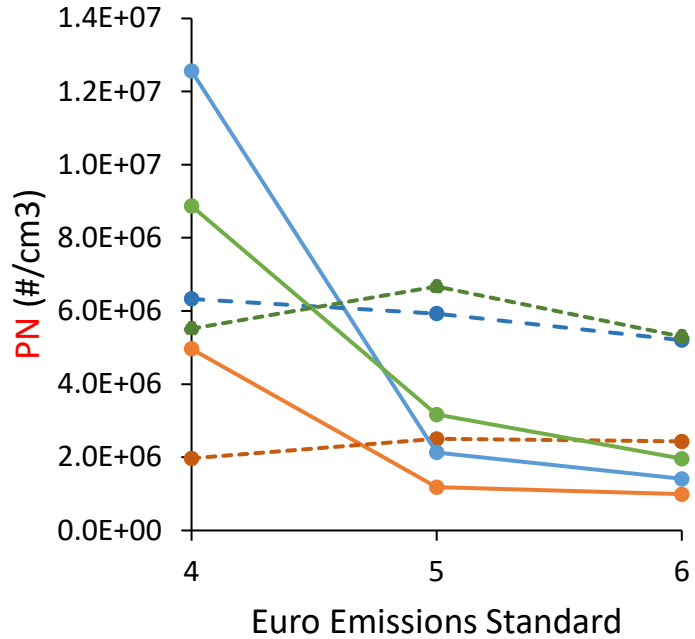




Evolution of fleet emissions by EURO stds - **Absolute**

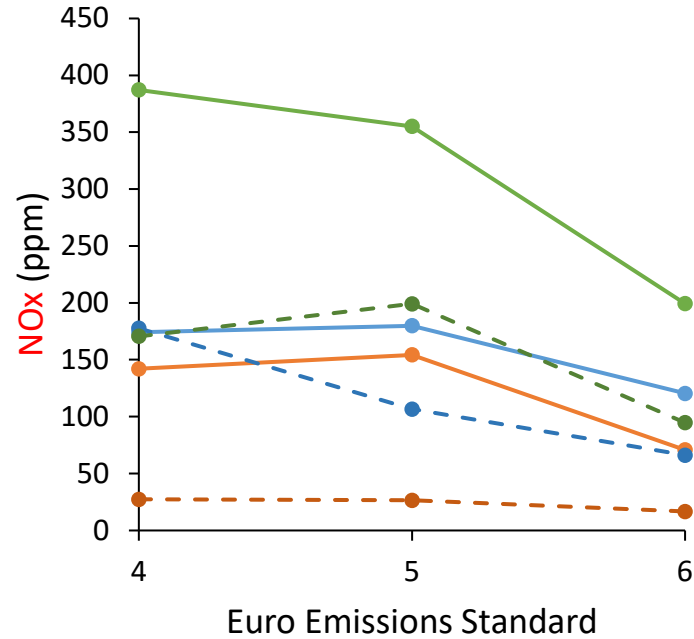
PN

- DPFs provide significant reduction from Euro 4 levels
- Petrol vehicles need more controls



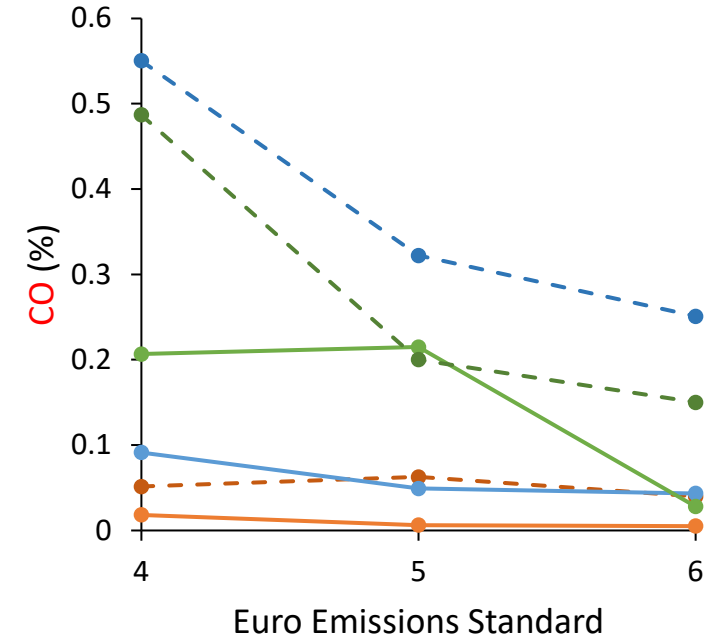
NOx

- Some emissions increased from Euro 4 to Euro 5
- All decreased to Euro 6



CO

- CO generally decreasing

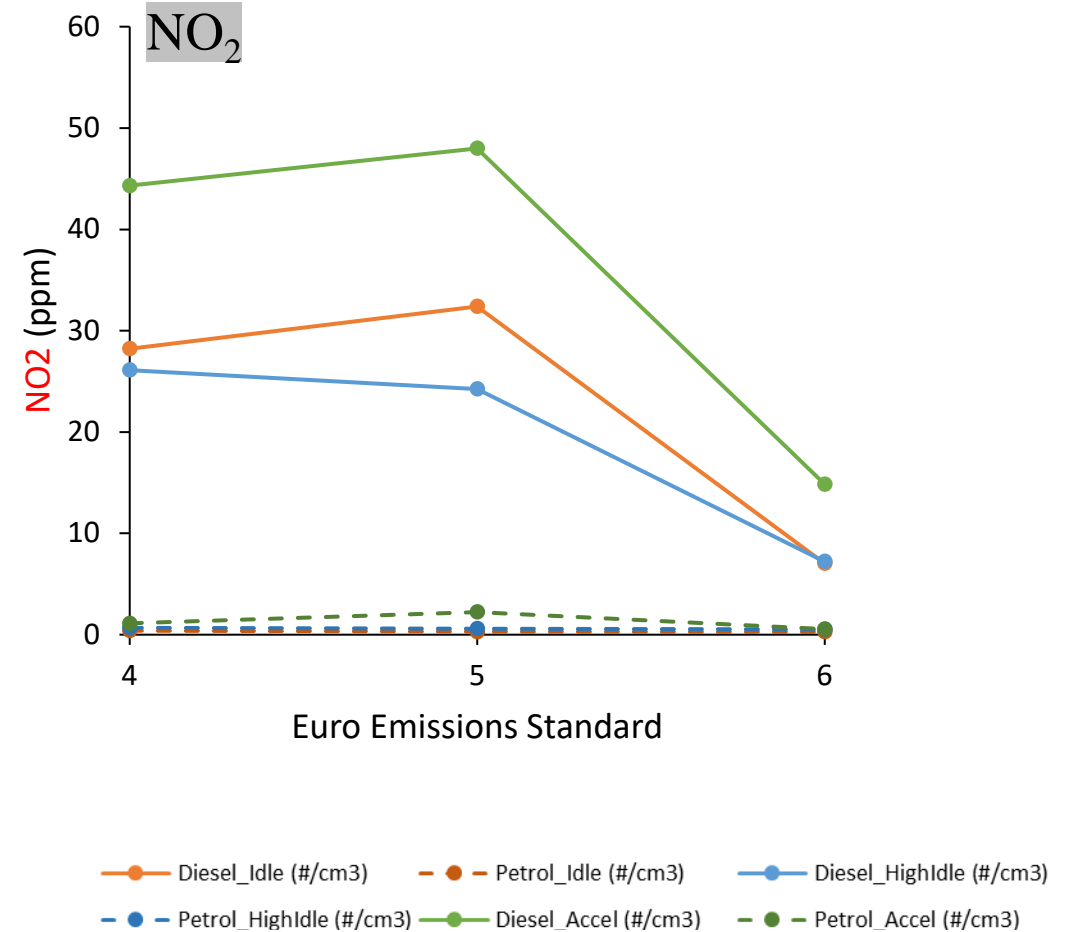
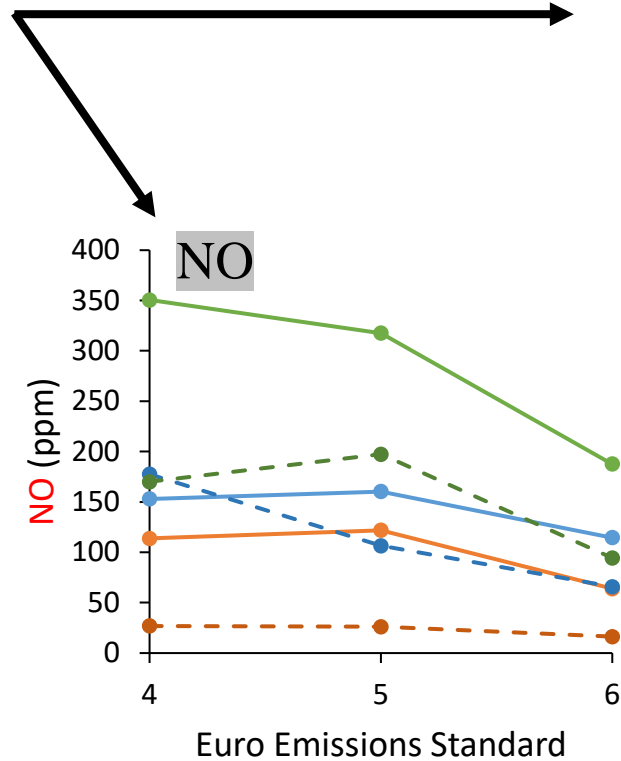
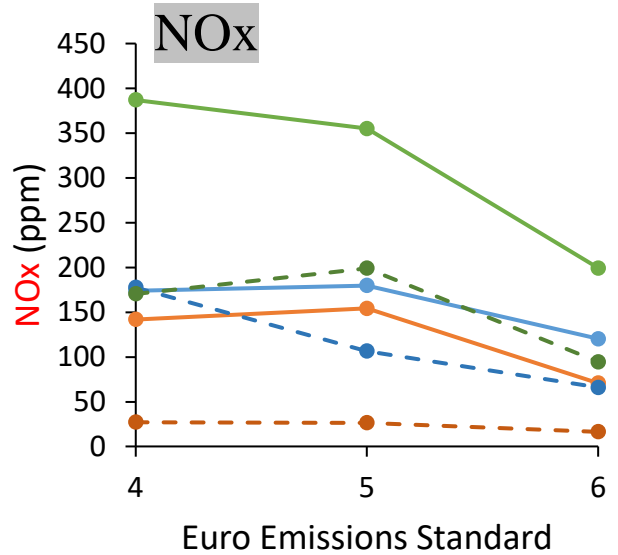


—●— Diesel_Idle (#/cm3)
 - -●- - Petrol_Idle (#/cm3)
 —●— Diesel_HighIdle (#/cm3)
- -●- - Petrol_HighIdle (#/cm3)
 —●— Diesel_Accel (#/cm3)
 - -●- - Petrol_Accel (#/cm3)



NO_x, NO, and NO₂ emissions by EURO stds – Absolute

NO_x-PTI threshold must include NO₂ in reported NO_x





Conclusions





Summary

- Deterioration of vehicles with mileage:
 - SCR equipped Euro-6 have significant deterioration (compared to non-SCR)
 - TWC has deterioration
 - DPF have deterioration but still reduce impact on PN
- Step decrease in diesel NO_x seen from model year 2017
- Acceleration test NO_x concentration has best correlation to type approval RDE emission factor.
- Future work will gather more RDE and NEDC/WLTC data for these vehicles, and expand on the vehicle characteristics investigated





Thank you for listening

3DATX Contact Info

See *Atmosphere* journal article for more info
– <https://www.mdpi.com/2073-4433/14/3/536>

USA



info@3datx.com



+1.844.303.3289



Gurdas S. Sandhu, Ph.D.

gurdas@3datx.com

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EU



info@3datx.eu



+32.2.639.39.39



Daisy Thomas, Ph.D.

daisythomas@3datx.com

Further Info

Full study and time-series graphs of ALL tested vehicles:

<https://3datx.com/ptipilot/>





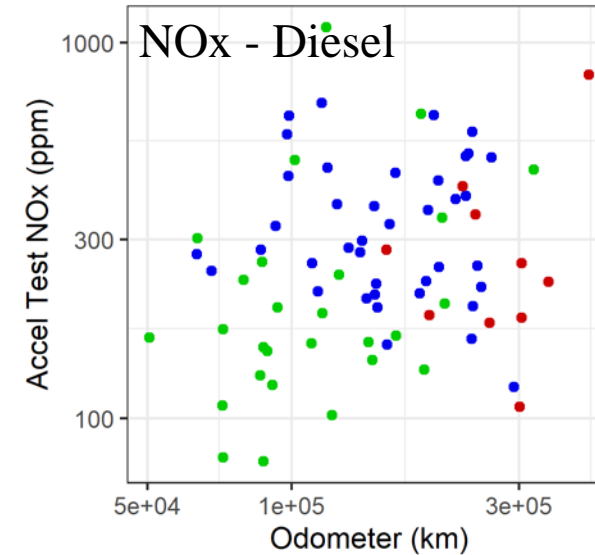
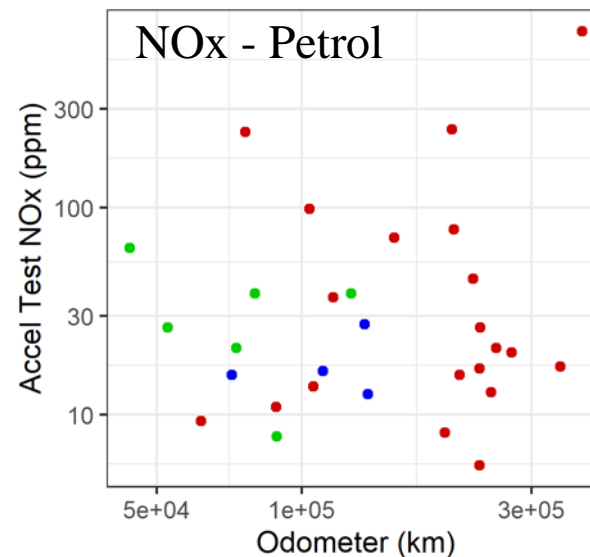
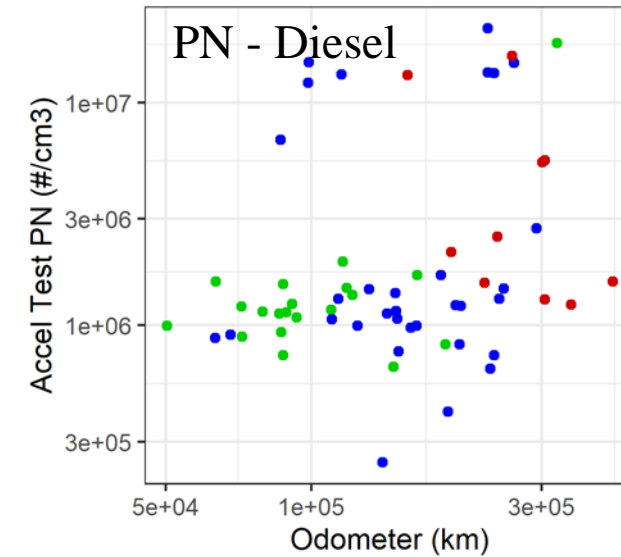
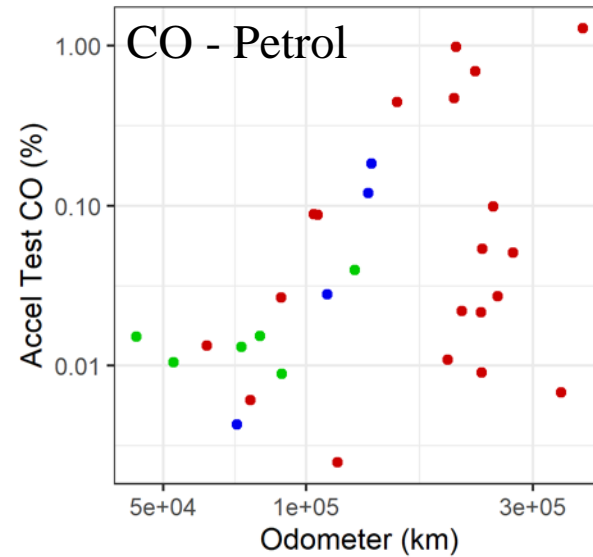
Additional Slides





Mileage Trend Focus on One Vehicle Make - Volvo

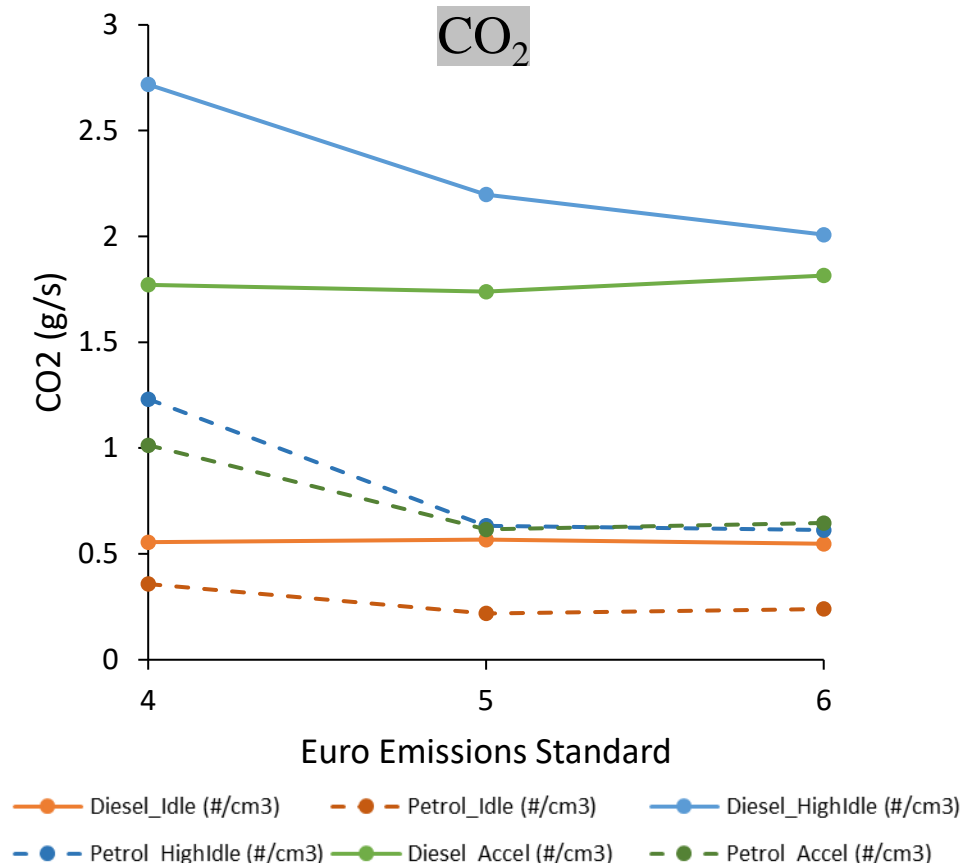
Plotting only Volvo vehicles, same increasing NOx vs mileage for Euro 6 (SCR) diesels seen





CO₂ emissions by EURO stds - **Absolute**

CO₂ from vehicles has decreased from Euro 4 to Euro 5 but little change seen going from Euro 5 to Euro 6 emission standard vehicles.



Engine power and size decrease from Euro 4 to 5, but power and weight increase to Euro 6

Euro Standard	Engine Size (L)	Engine Power (kW)	Total Weight (kg)
Euro 4	1.92	104	1912
Euro 5	1.79	102	2039
Euro 6	1.76	113	2025

Euro Standard	Engine Size (L)	Engine Power (kW)	Total Weight (kg)
Euro 4 diesel	2.13	115	2134
Euro 5 diesel	1.97	110	2206
Euro 6 diesel	2.05	127	2215

Euro Standard	Engine Size (L)	Engine Power (kW)	Total Weight (kg)
Euro 4 petrol	1.84	100	1834
Euro 5 petrol	1.46	87	1741
Euro 6 petrol	1.42	96	1795

